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Real-time control of MHD instabilities using ECCD

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For ITER and also future devices like DEMO, the capability to control magneto-hydrodynamic (MHD) instabilities like sawteeth and neoclassical tearing modes (NTM) is required to ensure reliable high β plasma operation. Such plasmas naturally encounter these phenomena, some of which are performance limiting at best but destructive in the worst case as NTMs may cause disruptions. A tried and trusted actuator with which these instabilities can be strongly influenced and eventually controlled is electron cyclotron resonance heating and current drive.

ASDEX Upgrade is making a large effort to develop, operate and evaluate an ECCD based, generic solution to MHD control, easily portable to new devices like ITER. Depending on the control strategy with highest priority, be it sawteeth or NTMs, ECCD deposition may need to be targeted at different radial locations, but the general control scheme is very similar, hence a so-called supervisory controller can delegate tasks to lower-level controllers and achieve a globally ideal solution given the existing constraints. Moreover, thanks to its generality, it can easily be adopted by other plasma experiments. TCV, among others, has started similar programs.

In order to achieve precise deposition control, a large number of real-time diagnostics and intelligent controllers work in unison, all coordinated by the discharge control system (DCS). In addition to the real-time equilibrium reconstruction, which is essential for our application, we require density profile measurements, real-time detection of MHD marker positions (rational surfaces, inversion radius, etc.) and some global plasma parameters (I_p, β_{pol}) which complement the dataset on which the controllers base their decisions.

Using the system in closed loop operation with 4 completely independent actuators, we have achieved controlled stabilization of 3/2 NTMs at β_N of 1.8 and preemption of NTM onset using the same control mode reaching β_N of 2.3 without mode. The system can automatically identify magnetic islands and aim stabilizing ECCD at the appropriate rational surfaces. Newly introduced deposition sweeping schemes alleviate the deposition accuracy requirement for NTM stabilization such that even imperfectly measured flux surface geometry is not prohibitive for achieving the intended goal.

The controller approaches maturity and is undergoing optimizations to improve its performance and reliability. For this step, we employ detailed data analysis with a beam tracing code to determine the physical limits of successful stabilization. In the case of NTMs these are dependent on the ratio of externally driven current to bootstrap current at the location of the magnetic island. Detailed analysis and a full system overview are being presented.

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Eligible for student paper award?

No

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